## 3.0 GROUNDWATER CIRCULATION WELL SYSTEM

This section describes the GCW system, including the design and principle of operation, GCW installation, hydraulic conditions near the GCW, and operational modes of the GCW. Table 1 is a chronology of field events associated with installation and operation of the GCW.

### 3.1 DESIGN AND PRINCIPLE OF OPERATION

The WEI GCW is an in situ groundwater remediation system designed to simultaneously circulate and strip VOCs from groundwater in the aquifer. In the WEI system, airlift pumping moves groundwater upward from a screen in the lower section of the well. Air is pumped to the bottom of the well using a blower, reducing the weight of the water column. Groundwater and air are then lifted to an upper screen, where the air strips VOCs and the groundwater is allowed to discharge back into the aquifer. The air stream used to strip VOCs is extracted from the wellhead and is treated before it is released to the atmosphere. Groundwater that re-enters the aquifer via the top screen flows vertically downward and can be recaptured by the GCW, where it is treated again. The groundwater flow regime developed by the GCW is termed a circulation cell, and its characteristics are critical to the effectiveness of the technology. Key parameters of the circulation cell are its size, or radius, and its percent capture (Parsons 1999a).

For the demonstration at CCAS, the design of the GCW was modified to include an eductor pipe. The eductor pipe was installed inside the GCW to prevent air bubbles from escaping from the lower screened interval and into the surrounding aquifer. The addition of the eductor pipe allows air-lift pumping operation of the GCW without exposing the GCW intake screen (lower screen) to air bubbles.

### 3.2 INSTALLATION OF GROUNDWATER CIRCULATION WELL[1]

The GCW system at CCAS Facility 1381 was installed in November 1999. A schematic diagram of the GCW is presented as Figure 7. The GCW system is a 6-inch-diameter PVC well casing with two separate, wire-wrapped PVC well screens, installed to a total depth of 35 feet bgs. The upper screened interval is 5 feet long and was installed from 5 to 10 feet bgs using a 20-slot (0.020-inch), wire-wrapped PVC screen. The lower screened interval is 10 feet long and was installed from a depth of 20 to 30 feet bgs using a 10-slot (0.010-inch), wire-wrapped PVC screen. A 5-foot long sump was installed at a depth

[1] All pipe diameters and lengths are listed in American Standard Engineering units. Please see page xiv for conversion factors for metric units.

of 30 to 35 feet bgs, below the intake screen of the lower screened interval, to collect sediments. The entire sub-surface system was installed in a 14-inch diameter boring.

A filter pack that consisted of 20/45 silica sand was installed in the annulus around the intake (lower) screen from 18 to 35 feet bgs. Coarser-grained, 6/20 silica filter sand was installed in the annulus around the outflow (upper) screen from 0 to 11 feet bgs. The filter sand was installed using a tremie pipe and was surged every 5 feet to ensure that the filter pack settled. Alternating layers of bentonite clay and silica sand were poured in the annulus around the middle blank casing section between 11 and 18 feet bgs. The bentonite clay seals were installed to prevent downward flow of water through the annulus.

The eductor pipe was constructed of 4-inch-diameter PVC to simulate the airlift performance of a 4-inch-diameter GCW. The eductor pipe is perforated from 3 to 5.5 feet bgs and from 29.5 to 31 feet bgs. The perforations consist of 0.5-inch diameter holes in four lines spaced radially around the pipe, approximately 4 inches apart vertically.

Two piezometers were installed within the sand pack of the 14-inch diameter GCW boring. The upper piezometer, GCWS, was screened from 7 to 8 feet bgs, adjacent to the upper screened interval of the GCW. The lower piezometer, GCWD, was screened from 24.5 to 25.5 feet bgs, adjacent to the lower screened interval of the GCW. Figure 6 shows piezometers GCWS and GCWD in relation to the GCW.

Four piezometer pairs, each consisting of 1.5-inch-diameter shallow and deep piezometers (2PZS/2PZD, 3PZS/3PZD, 4PZS/4PZD, and 6PZS/6PZD) were installed within a 30-foot radius of the GCW. Except for 6PZS, these piezometers were used as observation wells during aquifer hydraulic testing. The piezometers were screened at intervals of approximately 6 to 9.5 feet (shallow) and 22 to 26 feet (deep) bgs.

## 3.3 HYDRAULIC CONDITIONS NEAR THE GROUNDWATER CIRCULATION WELL

This section discusses hydraulic conditions near the GCW by defining the aquifer zones screened by the GCW and describing the natural patterns of groundwater flow near the GCW.

### 3.3.1 Definition of Screened Aquifer Zones

The upper screen of the GCW was installed at a depth of 5 to 10 feet bgs and is completed in the shallow aquifer zone. The shallow aquifer zone consists predominantly of coarse shell fragments and coarse to medium sand with little or no silt and no clay.

The lower screen of the GCW was placed at a depth of 20 to 30 feet bgs in the deep aquifer zone. The lithology of the deep aquifer zone is described as predominantly medium to very fine sand with little or no silt or clay, possibly containing significant amounts of shell fragments. A lower part of the deep aquifer zone consists of fine sand and silt.

Piezometer pairs near the GCW were installed in either the shallow (S-series) or the deep (D-series) aquifer zones.

### 3.3.2 Natural Groundwater Flow Conditions

Site groundwater elevations measured in 1996 indicated that site groundwater appears to be affected by a northwest-trending groundwater divide (Parsons 2000). The divide directs groundwater flow to the southwest toward Landfill Canal, and to the northeast. The groundwater divide is present in both the shallow and deep aquifer zones, although the location of the divide may differ in the two aquifer zones. As a result of the divide, direction of groundwater flow beneath Facility 1381 may be temporally variable, as the groundwater divide moves laterally in response to changes in water levels in the canal and infiltration recharge rates.

Data on groundwater elevations were collected in the deep and shallow piezometers near the GCW during natural flow conditions on separate dates in April, June, and July 2000 (Parsons 2000). Table 2 summarizes directions of groundwater flow. The data indicate that directions of flow in both the shallow and deep zones reversed during the 4-month period. The direction of groundwater flow in the shallow aquifer zone shifted between flow to the northwest and flow to the south and southeast. Similarly, the direction of groundwater flow in the deep aquifer zone shifted between flow to the north/northwest and flow to the southeast. However, the direction of flow in the deep and shallow aquifer zones were the same in April and mid-June, but were different from each other in late June and early July. The combination of the low horizontal hydraulic gradient and recharge effects of the canals most likely cause constant fluctuations in the direction of groundwater flow near the GCW.

The information presented in Table 2 indicates that the directions of groundwater flow in both the shallow and deep aquifer zones are variable and can vary between the two aquifer zones at the same time. The information confirms that a groundwater flow divide exists near the GCW. As a result, no dominant direction of flow can be identified in either aquifer zone.

## 3.4 GCW OPERATIONS

During the demonstration the GCW was operated in four operational modes: GCW circulation, pump-and-treat testing, aquifer testing, and dipole flow testing (DFT). This section describes GCW operation in each mode.

### 3.4.1 GCW Circulation

AFCEE operated the GCW in circulation mode during the spring and summer of 2000. The setup of the GCW in circulation mode is shown as a schematic diagram in Figure 8. An air supply pipe, constructed of 0.75-inch PVC, was inserted in the GCW within the eductor pipe. Pressurized air was then supplied to the well via piping fitted with a pressure gauge and a flow meter, which measured airflow to the GCW. A section of 1.5-inch-diameter PVC pipe was attached to the end of the air supply pipe to direct airflow upward within the eductor pipe. Air was injected into the GCW at a depth of approximately 29 feet bgs.

After several weeks of operation in this mode, evidence of scaling or accumulation of calcium carbonate was noted in the GCW. The scaling occurs when carbon dioxide is stripped from the water as it flows through a well, when the pH of the water increases to the point that calcium carbonate is oversaturated and begins to precipitate. As a result, an acid drip system was installed, which began operating on May 5, 2000, to maintain the pH of the water and reduce scaling. The acid drip system consisted of a 5-gallon acid container and a metered pump that discharged acid to the top of the air supply pipe. A hydrochloric acid solution with a pH of slightly above 2.0 standard units was injected into the well at the air discharge point, where the surging action of the airlift pumping would promote maximum mixing. The acid injection rate was adjusted in an attempt to maintain the pH of the outflow water as near as possible to the pH of the inflow water. The 5-gallon storage container was subsequently replaced with a 30-gallon container to permit increases in the rate of acid addition. The acid injection system is shown schematically in Figure 8.

During the circulation mode of operation, AFCEE conducted three types of tracer tests to assess the performance of the GCW. Flow rate testing using bromide was performed to provide a direct measure of flow through the GCW. A second test using sulphur hexafluoride ($SF_6$) assessed the extent of recirculation for flow out of the upper GCW screen back to the lower well screen. A third test using fluorescent dye evaluated movement of water away from the GCW and into the aquifer.

### 3.4.2 Pump-and-Treat Testing

AFCEE conducted groundwater pump-and-treat tests both before and after operation of the GCW in circulation mode to allow a comparison of the circulation operation results with results obtained using a more conventional technology (pump-and-treat). A schematic diagram of the pump-and-treat system is shown in Figure 9. A ½-horsepower (HP) electric submersible pump was installed in the 4-inch ID eductor pipe in the lower screened interval of the GCW at a depth of approximately 28 feet bgs to conduct the pump-and-treat operation.

Operation of the GCW during the pump-and-treat test consisted of pumping water from the lower screened interval. The extracted water was pumped into a holding tank and then treated using an air-stripping unit. The treated effluent was then piped to an infiltration zone for discharge by a sprinkler system.

### 3.4.3 Aquifer Hydraulic Testing

EPA conducted aquifer hydraulic testing using the lower screened interval of the GCW as the pumping well. An inflatable packer was used to isolate the two screened intervals to facilitate pumping from only the lower screened interval. Figure 10 is a schematic diagram of the aquifer testing system at the GCW.

Aquifer hydraulic tests consisted of a step drawdown test, a DFT, and a constant-rate pumping test. Objectives and results of the aquifer testing are presented in Appendix A, the Hydrogeological Investigation Report.

### 3.4.4 Dipole Flow Testing

EPA conducted multiple DFTs using the GCW on September 14 and 18, 2000. Figure 11 is a schematic diagram of the setup for the DFTs. The DFTs were conducted by simultaneously pumping water from the lower screened interval in the deep aquifer zone and injecting the discharged groundwater into the upper screened interval in the shallow aquifer zone. The pumping rate was equal to the injection rate during each of the DFTs. Water levels in piezometers GCWD, GCWS, 2PZD, 2PZS, 3PZD, 3PZS, 4PZD, 4PZS, and 6PZD were monitored using Insitu® mini-TROLL pressure transducers and data loggers.

Five separate tests were completed at different flow rates during the DFTs conducted on September 14, 2000. Groundwater was pumped and injected simultaneously at rates of 2.3, 3.7, 6.0, 8.8, and 4.8 gallons per minute (gpm) in periods that lasted 30 minutes each, except for the final test, which lasted 90 minutes. A recovery period of 30 minutes was allowed between each test. The 30-minute recovery period after each DFT was considered adequate because relatively fast recovery in the water level was observed in the lower and upper screened intervals of the GCW during the step-drawdown tests. Groundwater hydrographs for piezometers GCWS and GCWD during Dipole Tests 1 through 5 (see Appendix A) demonstrate that the 30-minute recovery period between tests was adequate.

An additional DFT (Dipole Test 6) was conducted on September 18, 2000 using a higher flow rate and a longer test period, specifically pumping and injecting groundwater at a rate of 12.5 gpm for 142 minutes. The DFT was stopped prior to its full duration because of a power failure and, as a result, logarithmic data for the water level recovery could not be collected for the early portion of the test. A second high-flow/long-duration DFT (Dipole Test 7) was conducted later on September 18, at a pumping and injection rate of 12.5 gpm for 360 minutes.